Does Explicit Analogical Reasoning Help Second Language Acquisition? Evidence From Artificial Language Learning

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Abstract

When people acquire a second language (L2), do they benefit from analogical reasoning? Past research showed that people are likely to engage in analogical reasoning to support their L2 learning, yet it is unclear whether this process is explicit or only occurs automatically and implicitly. In the current study, English-speaking participants (N = 100) learned a miniature artificial language with grammatical markers that were either morphologically congruent or incongruent with English grammar. We then assessed participants' acquisition of the artificial language and their explicit use of analogical reasoning. Acquisition was improved when the artificial language was structurally congruent with English, and was also better with participants who reported explicit analogical reasoning. This was especially pronounced for the ability to generate novel content. These findings provide evidence that learners acquiring a new language spontaneously leverage analogies with their existing languages, and this is especially beneficial when the analogies are recognized explicitly.

Keywords: Analogical reasoning; second language acquisition; bilingualism; language transfer; learning strategy; artificial language

Introduction

Learning a second language (L2) is a widespread phenomenon. In a recent survey, 74.6% of adults in the European Union reported speaking one or more foreign languages (Eurostat, 2024). For some populations, L2 is not just a fun skill but a necessity. For instance, in the state of California, USA, English learners comprise 19% of total public school enrollment; for these students, L2 (English) learning decisively determines their academic success (California Department of Education, 2024). Yet, L2 learning is challenging, especially for learners who start late (DeKeyser, 2010). Given that L2 learning is both prevalent and challenging, understanding the mechanism of L2 acquisition is particularly important.

One potential strategy that could help learners overcome the challenge of L2 learning is analogical reasoning. Analogical reasoning occurs when people match relational similarities between a familiar system of concepts (*source domain*) and an unfamiliar one (*target domain*), enabling learners to leverage their existing knowledge of the source domain to better understand the target domain (Gentner & Maravilla, 2018). Analogical reasoning has been found to scaffold more efficient learning in several domains, including math, business negotiations, biology, and geoscience (Richland & Hansen, 2013; Gentner et al., 2003; Gadgil et al., 2012; Jee et al., 2013; Venditti et al., 2015). The existence of relational similarities between languages raises the possibility that analogical reasoning could also sometimes help L2 learning. Learners could match relationally similar structures from their native language (*source domain*) to L2 (*target domain*), facilitating L2 acquisition. For instance, learning the grammatical tense system of a new language might be facilitated if it has similarities with the tense system of the learner's native language, perhaps by mapping the placement of the grammatical markers and the tense types onto their L1 counterparts.

There is some evidence that analogical reasoning supports L2 acquisition. For instance, L2 learning is better when the L2 more closely resembles the learner's native language. In a study of Dutch acquisition by speakers of 62 different native languages, the phonological, morphological, and lexical similarities between the learner's native language and Dutch jointly explained about 80% of the variance in Dutch speaking proficiency, after controlling for non-linguistic factors that are known to influence language acquisition (Schpens et al., 2020). One interpretation of this finding is that the similarity between the native language and Dutch allowed analogical reasoning. Specifically, when the L2 (Dutch) was more similar to a learner's native language, the languages were more alignable, enabling more usage of analogical reasoning when learning the L2. Other evidence for the role of analogical reasoning in L2 acquisition comes from patterns of L2 errors. Learners often struggle to learn L2 features that are absent from their native language. For instance, English learners whose native language does not have articles exhibit challenges in learning and using English articles (Ionin, 2009, 2022), perhaps because the absence of alignable structure interferes with learning. Thus, acquiring an L2 can be facilitated when it is alignable with the learner's native language, and learners struggle specifically with those

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aspects of the L2 that are not alignable, which is consistent with the proposal that analogical reasoning plays a role during L2 acquisition.

However, while previous research suggests that analogical reasoning plays a role in L2 acquisition, it remains unclear whether this is an explicit strategy that L2 learners adopt consciously. One alternative explanation for the facilitating effect of between-language similarity is that analogical reasoning occurs without the learner's awareness. This is plausible because analogical reasoning in other domains has been found to occur implicitly and unintentionally. For instance, one study found that previously read relationally similar stories shaped participants' comprehension of a new story, yet most participants did not report using analogical reasoning (Day & Gentner, 2007). Similarly, in the context of L2 learning, learners might unconsciously align L2 with their native language, thus facilitating learning, without explicit awareness that they are engaging in analogical reasoning. Indeed, whereas some studies have reported benefits of L1 similarity during L2 acquisition, others have failed to find benefits of explicitly instructing L2 learners to compare the L2 with their native language — that is, to engage in analogical reasoning (Whitman & Jackson, 1972; Tolentino & Tokowicz, 2014; Otwinowska et al., 2020). Such findings suggest that, if L2 learners *do* rely on analogical reasoning, it may happen automatically and unconsciously, so explicit attention to the process of structural alignment and analogical reasoning may be unnecessary and inefficient; indeed, drawing explicit attention to the process may even interfere.

Here, we investigate whether analogical reasoning during L2 acquisition involves a conscious, explicit process. We adapted an artificial language learning paradigm that has been used previously to study the role of alignable structure in L2 acquisition (Baptista et al., 2016; Labotka et al., 2023). In this paradigm, English-speaking participants are taught a miniature artificial language through brief training on vocabulary and sentences with negation and plurality. Importantly, the grammatical markers of negation and plurality are manipulated to be either morphologically congruent with English (i.e., "nat," similar to English "not," and "iss," similar to the English "–s" suffix, respectively) or incongruent with English ("plick" and "mut," respectively). Past studies have shown that acquisition is improved in the congruent condition, in which L2 negation and plurality are alignable with the learners' native language (Baptista et al., 2016; Labotka et al., 2023). It is possible that participants were better able to structurally map the meaning, morphology, and phonology of the artificial language's grammatical markers to their English counterparts in the congruent condition, by reducing cognitive load and facilitating more efficient encoding of Zamperses grammatical markers. This artificial language learning paradigm thus allows for the targeted investigation of the role of structural alignment and analogical reasoning in L2 acquisition. In the current study, we investigate whether participants benefit from spontaneous awareness of the structural similarities between the L2 and their native language, and from explicitly implementing analogical reasoning as a strategy. To this end, we incorporate an additional survey into the paradigm to assess participants' explicit awareness of the similarities and usage of analogical reasoning during the artificial L2 learning process.

If the benefits of structural alignment depend on the learner drawing an explicit analogy between their native language and the L2, then participants who report explicit cross-language mapping should perform better in learning the L2. Alternatively, if the benefits of structural alignment reflect an implicit process of cross-linguistic alignment, we expect to observe that the congruency between languages improves performance even without participants reporting explicit analogical reasoning. Additionally, we explored whether the benefits of analogy are targeted, benefiting only those aspects of the language that are alignable, or more general, with broad benefits for all aspects of acquisition. For instance, alignable grammatical morphology might have targeted benefits for generating new sentences that use those alignable elements, rather than, say, memorizing the semantics of other words.

Method

Participants

We recruited 100 undergraduate participants (48 female, 20 male, 2 non-binary, 30 no response; mean age = 19.9) from a university on the West Coast of the USA, who participated in return for course credit. The university is designated a Hispanic-serving institution (greater than 25% of full-time undergraduate students are Hispanic or Latino). All participants were proficient in English. Most participants were bilingual (87%), and Spanish was the most common language other than English.

Design

The study was completed online and implemented using Gorilla Experiment Builder (www.gorilla.sc), a platform for creating online behavioral studies (Anwyl-Irvine et al., 2021). Participants were tasked with learning an artificial language, and we manipulated whether the artificial language shared structure regularities with English. We adapted the miniature artificial language, *Zamperese*, from the materials of Baptista et al. (2016) and Labotka et al. (2023). *Zamperese* in the current study consisted of 4 nouns, 2 transitive verbs, 1 intransitive verb, and two grammatical markers (negation and plurality). The sentence structure was Subject-Verb-Object (SVO). In this artificial language, the plurality marker was placed after nouns, and the negation marker was placed after the verb. The structure of a grammatical sentence was thus as follows:

Noun-Subject [*Plural Marker*] Verb [*Negation Marker*]
Noun-Object [*Plural Marker*]

Critically, we randomly assigned participants to be trained and tested on either a *congruent* (n = 49) or an *incongruent* (n = 51) version of the language. In the *congruent* condition,

the grammatical markers for negation and plurality were morphologically similar to their English counterparts (negation: "nat", plurality: "iss"). In the *incongruent* condition, the grammatical markers were morphologically unrelated to their English counterparts (negation: "plick", plurality: "mut").

The study began with training in Zamperese, followed by a test of participants' mastery of Zamperese. The study ended with a post-test questionnaire of participants' learning strategies. We describe these procedures in detail below.

Artificial Language Training Procedure

After passing the audio access and attention checks, participants watched a 1.5-minute vocabulary training video and a 7.5-minute sentence training video. In the vocabulary training video, each word was read four times, accompanied by a visual display of the word's spelling and an illustration of its meaning (e.g., a cartoon drawing of a bird to illustrate the meaning of the *Zamperese* noun "*bilt*"; an animation of a hopping stick man to illustrate the *Zamperese* verb "*lato*", which means hop). Participants then watched the sentence training consisting of 20 sentences (5 without negation or plurality, 5 with negation, 5 with plurality, and 5 with both) of their assigned version of *Zamperese*. Each sentence was read four times with its spelling and animation. Participants could only watch each training video once, and they were not allowed to pause or rewind during the videos.

Artificial Language Testing Procedure

After the training, participants received a 5 to 8-minute distraction session consisting of short breaks and a prisoner's dilemma game. Then, participants completed a four-part assessment of their competence with *Zamperese*: a vocabulary matching task, a sentence completion task, a grammaticality judgment task, and a sentence generation task.

First, in a vocabulary-matching task, participants were presented with the content words (N = 7) learned during the training and visual illustrations of the words' meanings. Participants were asked to match each word to the illustration of its meaning.

Second, in a sentence completion task, participants were presented with sentences with missing grammatical markers (N = 5 with missing negation marker and N = 5 with missing plurality marker) and were asked to fill in the blanks. Each sentence was accompanied by a picture illustrating its meaning.

Third, in a grammaticality task, participants rated the grammaticality of sentences (N = 23) on a Likert scale from 1 (ungrammatical) to 7 (grammatical). The items included a mix of grammatical (n =10) and ungrammatical sentences (n = 13). Most sentences involved some form of grammatical marker (n = 7 involved negation; n = 8 involved plurality).

Fourth and finally, in a sentence generation task, participants were asked to modify a base sentence in *Zamperese* to match the meaning of a target English sentence. The base *Zamperese* sentences (N = 16) were non-plural and non-negative, and they were constructed using eight *Zamperese* nouns and verbs that the participants had not seen before. The target English sentences involved negation (n = 6), plurality (n = 6), or both (n = 4). Participants could modify the base *Zamperese* sentence by typing in additional grammatical markers (e.g., negation or plurality markers).

Post-Test Assessment of Learning Strategy

After the assessment of *Zamperese* competence, participants completed a funnel questionnaire that was designed to assess individual differences in the strategies used to learn the artificial language, particularly the explicit use of analogical reasoning. To reduce demand characteristics (e.g., participants indicating that they had used analogical reasoning when asked), questions in this questionnaire began quite broadly and only gradually focused on the analogical mapping between *Zamperese* and English.

Participants first ranked the relative difficulty of learning each of the *Zamperese* words (4 nouns, 3 verbs, and 2 grammatical markers) by ordering them from easiest to hardest. Second, participants were asked explicitly whether their knowledge of English helped them learn *Zamperese*, and if they answered affirmative, they were asked to select up to three out of eight aspects of English that had been helpful when learning *Zamperese* (e.g. "Word Order", "Verbs", "Negation", "Plurality", etc.). Then, participants were asked a sequence of questions about the structure mapping between English and *Zamperese*: whether the *Zamperese* negation and plurality morphemes reminded them of any English word, and if so, which words; if any of the responses were affirmative, they were further asked whether the corresponding *Zamperese* grammatical morpheme(s) reminded them of the English morphemes "no" and "-s". Only participants who selected English negation and plurality as helpful when learning *Zamperese*, or responded affirmatively to the mapping questions were identified as "explicit analogical reasoners." We treated all skipped questions as negative responses when they were skipped based on negative responses on preceding questions in the funnel questionnaire.

Finally, we collected participants' language backgrounds using a modified version of the Bilingual Language Profile (Birdsong et al., 2012).

Analysis and Results

Analysis

Combining Section Scores. We normalized the responses on the four parts of the assessment into binary outcomes (correct/incorrect) to support a joint logistic regression model on general *Zamperese* performance. The vocabulary matching and sentence completion task originally used

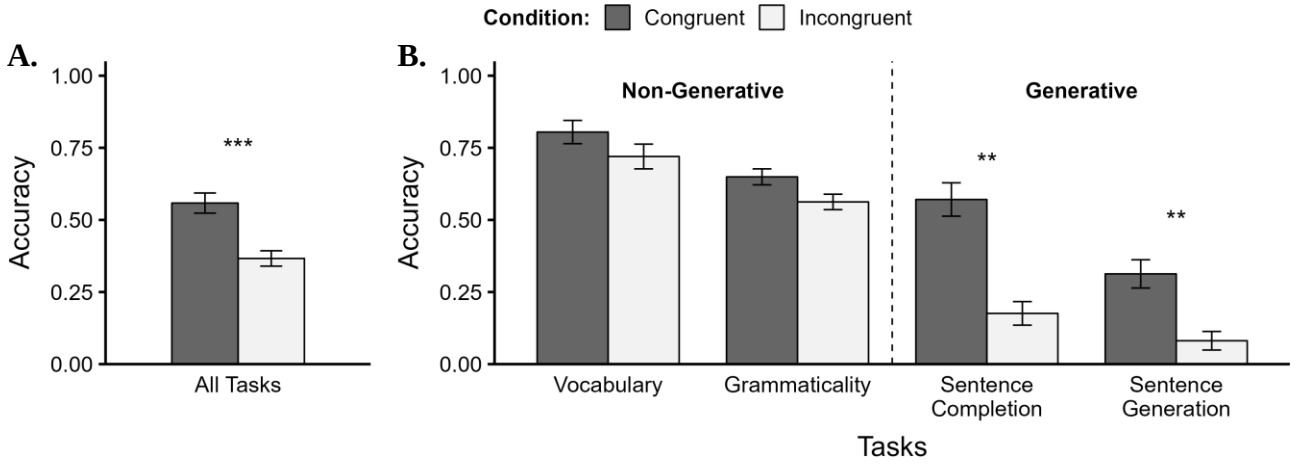

Figure 1: Participant's average accuracy on the assessment tasks in each condition. (A) Combining all four tasks, participants were more accurate in the congruent condition. (B) This effect was especially robust in the generative tasks (sentence completion & sentence generation). For the non-generative tasks, the accuracy did not differ significantly between conditions. (Error bars = standard error, ** $p < .01$, *** $p < .001$)

binary outcomes. For the grammaticality judgment task, a response was considered correct when the rating was greater than 4 for grammatical sentences or less than 4 for ungrammatical sentences. For the sentence generation task, a response was deemed correct when the grammatical marker(s) were included, correctly spelled, and correctly placed, regardless of the correctness of other parts of the sentence.

We recognized the possibilities of inattentive responses in the sentence completion, grammaticality, and sentence generation tasks. To ensure data quality, we excluded responses that took less than 1000ms in the sentence completion and grammaticality judgment task. In addition, if the participant had more than half of the responses excluded in a task, all responses from this participant on this task were excluded. For the sentence generation task, we excluded all empty responses and excluded the participants if they had more than 3 empty responses.

Explicit Analogical Reasoning Scoring. To analyze the effect of explicit cross-language mapping from English when learning Zamperese, participants' responses on the funnel questionnaire were scored based on the number of affirmative responses to questions reflecting explicit analogical reasoning processes. Participants received a maximum of 3 points, with one point granted for each of the following: (1) selected either English negation or plurality as helpful for learning Zamperese, (2) responded affirmatively that either Zamperese negation or plurality reminded them of any English word, and (3) indicated that either Zamperese negation or plurality reminded them of English "no" or "-s".

Results

After exclusion procedures, we included 97% of responses from 98 participants in the sentence completion task, 91% of responses from 91 participants in the grammaticality judgment task, and 93.6% of responses from 94 participants in the sentence generation task. 92% of participants in the congruent condition and 59% in the incongruent condition scored above 0 on explicit analogical reasoning score.

We logistically regressed the correctness of the response of each item to whether the participant received the congruent condition, whether the task of the item is generative (sentence completion & sentence generation), the participant's explicit analogical reasoning score, the interaction between condition and generative task, and the interaction between explicit analogical reasoning score and generative task. The model accounted for between-item and between-participant variability with random slopes.

As expected, the artificial language was learned significantly better in the English congruent condition (M = 0.55±0.03 SE) than in the incongruent condition(M = 0.37±0.03 SE) (Figure 1). The congruent condition positively predicted participants' overall performance of Zamperese ($b = 1.49 \pm 0.33$ SE, $p < .001$), which is consistent with Baptista et al, 2016, and Labotka et al., 2023, using the same paradigm. At the same time, participants who reported more explicit analogical reasoning appeared to learn the language better. As shown in Figure 2, a significant positive effect of explicit analogical reasoning score on performance was observed ($b = 0.79 \pm 0.15$ SE, $p < .001$).

Moving on to the types of assessment tasks, the non-generative items (M = 0.63±0.02 SE) are significantly easier

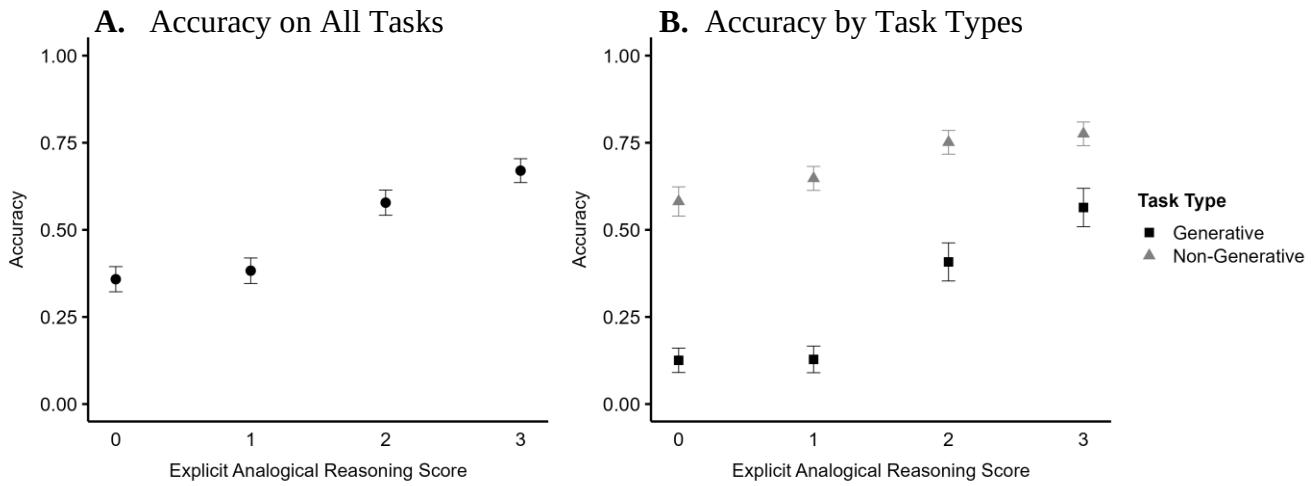

Figure 2: Participant's average accuracy on the assessment tasks by explicit analogical reasoning score. (A) Combining all four tasks, participants with higher explicit analogical reasoning scores were more accurate. (B) The effect was stronger when the task was generative (sentence completion & sentence generation). (Error bars = standard error)

in terms of accuracy compared to the generative items (M = 0.27±0.03 SE, b = 3.67 ± 0.26 SE, p < .001). Importantly, (non) generative items significantly interacted with the congruent condition (b = -1.41 ± 0.19 SE, p < .001) and explicit analogical reasoning scores (b = -0.43± 0.09 SE, p < .001) respectively, suggesting the positive effect of the congruent condition and explicit analogical reasoning scores was reduced for non-generative items.

To unpack these interactions, we conducted four additional separate models for each assessment task. Each of the models included the congruent condition and explicit analogical reasoning score as predictors, and the same random effect as the main analysis model. Condition significantly predicted better performance on the sentence completion ($M_{congruent}$ = 0.57± 0.06 SE, $M_{incongruent}$ = 0.18± 0.04 SE, b = 3.44 ± 1.15 SE, p = .003) and sentence generation task ($M_{congruent}$ = 0.31± 0.05 SE, $M_{incongruent}$ = 0.08± 0.03 SE, b = 2.65 ± 1.07 SE, p = .01), but not for the vocabulary-matching ($M_{congruent}$ = 0.80± 0.04 SE, $M_{incongruent}$ = 0.72± 0.04 SE, b = 0.07 ± 0.72 SE, p = .93) and grammaticality ($M_{congruent}$ = 0.65± 0.03 SE, $M_{incongruent}$ = 0.56± 0.03 SE, b = 0.06 ± 0.18 SE, p = .73) tasks. In comparison, the explicit analogical reasoning score significantly predicted better performance on the vocabulary-matching (b = 0.76 ± 0.34 SE, p = .03), sentence completion (b = 1.47 ± 0.49 SE, p = .003), sentence generation (b = 1.26 ± 0.49 SE, p = .01), and grammaticality tasks (b = 0.24 ± 0.08 SE, p = .004.)

Discussion

We set out to investigate whether the benefits of analogical reasoning for L2 acquisition are highest when the analogy is noticed explicitly. The results are consistent with past studies using the same paradigm (Baptista et al, 2016; Labotka et al., 2023). The morphologically congruent condition outperformed the incongruent condition significantly, indicating participants were better at learning an artificial language when its morphology was analogous to their familiar language (English). Further, as predicted, more explicit analogical reasoning robustly predicted better language learning performance, suggesting L2 learners benefited from explicit analogical reasoning. Interestingly, while generative tasks are harder, we found both the effects of condition and explicit analogical reasoning to be stronger on those tasks. This suggests participants potentially receive greater benefit from the congruent condition and explicit analogical reasoning on those tasks. The result is not surprising as the two generative tasks had a stronger focus on morphology, which was manipulated for congruency with English during the study.

Perhaps the most novel finding of the current study is that L2 learners may benefit from establishing more explicit structural mapping with a familiar language. This finding highlights that analogical reasoning may serve as an explicit, spontaneous, and efficient strategy for L2 learning. Therefore, it is plausible that the language proximity effects reported in past research (Schpens et al., 2020; Ionin, 2009, 2022) can, at least partially, be attributed to explicit analogical reasoning. Greater similarities between languages could promote analogical reasoning strategies, facilitating more efficient learning.

On the other hand, the effect of explicit analogical reasoning underscores the individual differences in analogical reasoning strategy use, which could be influential in language learning outcomes. Individual differences in spontaneous adoption of analogical reasoning reveal opportunities to enhance L2 learning by incorporating analogical reasoning scaffolding when languages share relationally similar linguistic features.

Another intriguing finding in the current study is that the effect of the congruent condition remained significant even when explicit analogical reasoning was a robust predictor in the model. This pattern suggests that the congruent condition

still outperformed the incongruent condition when holding the analogical reasoning score constant. Therefore, the independent effect of the congruent condition indicates that congruency between languages may provide benefits beyond supporting an explicit analogical reasoning strategy. Given that congruency was the only manipulation, and the past work still suggests plausible unintentional structural mapping (Day & Gentner, 2007), our finding opens the possibility of the coexistence of explicit and non-explicit analogical reasoning in L2 learning.

However, our study has some limitations that future studies should address to deepen the understanding of explicit analogical reasoning in L2 learning. First, our study used brief learning windows, which could limit participants' options for learning approaches, especially those that are effective but time-consuming (e.g., repetition). Also, although the assessment in this study was delayed from the training, the delay is transient in the context of long-term language acquisition. It remains an empirical question whether explicit analogical reasoning would offer considerable benefit in a more complicated long-term L2 learning process. Second, the current study relied on the observation of spontaneous explicit analogical reasoning, which might limit the causality of explicit analogical reasoning. That is, it is still possible that the benefit of congruency was caused by mechanisms other than analogical reasoning, such as lower-level morphological or phonological priming. It is also plausible that the analogical reasoning questions reflect a hindsight recognition of relational similarities. To further confirm the causal role of analogical reasoning, future studies should manipulate participants' usage of explicit analogical reasoning, perhaps through a scaffolding intervention. Third, the paradigm in the current study manipulated only the artificial language's morphological alignment with English, yet past research suggests potential alignment benefits for other linguistic aspects, including lexicon and grammar (Schpens et al., 2020; Pajak & Levy, 2014; Ionin, 2009, 2022). Therefore, future studies should target other relational similarities to comprehensively examine the generalizability of the current findings.

Our findings may help optimize learning in multilingual contexts and inform individual differences between L2 learners. Also, the findings could inform the design of L2 learning interventions by highlighting the potential benefit of explicitly instructing structural mapping between languages, which addresses the rising demand for L2 learning in education.

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